Chapter

2

The Facility Manager's Role in Earthquake Safety

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Introduction

Although the field of seismic safety is the domain of the engineering profession, funding to carry out a seismic safety program is normally derived from the budgets that managers (or owners) need to carry out the overall missions of their organizations. Consequently, it is generally managers rather than engineers who must make most of the key decisions that are needed to carry out an effective seismic safety program. It is also managers who must resolve issues of risk management that accompany seismic hazards and involve life safety, damage control, potential evacuation and relocation costs, and potential liabilities, as well as cost-benefit considerations. It is therefore very important that facility managers have a broad understanding of the comprehensive nature of an effective earthquake safety program as well as an awareness of the socio-political, legal, and economic risks that often impede the progress and success of such programs.

This chapter provides practical advice for owners or managers who must carry out earthquake safety programs. It is written from the perspective of an engineer who has had such an experience as a facility manager.

The scope, depth, and focus required to carry out a satisfactory program vary considerably with the age of a facility, the risk involved, and the quality of design that was applied during its construction history. For a new and growing facility, the focus is on design and construction. For an older facility, the need to evaluate existing conditions and prioritize projects for abatement of seismic hazards receives most attention. For the majority of sites, however, a balanced program is most effective in preventing further development of new hazards while reducing the backlog of old ones.

Structural engineers who are experienced in earthquake engineering and have reviewed a number of facilities, both in government and private enterprise, have found a wide variety of serious seismic deficiencies that owners or managers were unaware existed. This is not unusual even in areas of the country where seismic design provisions have been part of the building code for many years.

East of California, few conventional buildings in the United States have been designed for earthquakes, even where there has been a history of earthquakes of sufficient intensity to damage buildings. In locations where the potential for seismic destruction exists along with a legacy of hazardous buildings and contents, the prospect of carrying out a comprehensive earthquake safety program is indeed challenging.

Generally, managers responsible for operating major facilities are unfamiliar with earthquake engineering and tend to look for answers in techniques that are more sophisticated than those often required to solve the actual problems in earthquake safety. The approach to solving these problems often becomes so academic, ponderous, and expensive that abatement of the seismic hazards simply doesn't get done in a timely manner.

In recent years, the state-of-the-art in seismology, geotechnical theory, and dynamic analysis of structures has progressed tremendously. Spurred on by the need to resolve questions in seismic safety for nuclear power plants, the field has become very compartmentalized and specialized. The great strides made in these specialties have contributed significantly to the field of earthquake engineering and public safety. Unfortunately, it is easy for responsible managers or facilities engineers to *fall into a crack* between these experts who quite naturally tend to resolve seismic questions based on their own specialties.

More time and money can be expended analyzing the problems in earthquake safety than would be needed to design practical solutions to these same problems. To gain a better perspective, it is important to understand that most problems found in existing construction are a result of not implementing what has been known and observed about earthquake-resistant construction for a long time. Structural engineers who have observed and studied earthquake-damaged buildings are able to diagnose hazardous deficiencies in existing buildings rather easily and efficiently, often without complex calculations. They understand which building types are hazardous, and they know cost effective methods for rehabilitating them.

Selecting An Earthquake Safety Consultant

The most important thing managers can do to initiate an effective and economical earthquake safety program is to hire as consultants experienced earthquake engineers who are strong on design and tend to keep analysis straightforward and understandable. Occasionally, there is good reason to apply sophisticated techniques to provide a better understanding of a complex problem, but not very often. Earthquake engineers, working closely with managers, should advise on the selection of specialized consultants such as geotechnical engineers or seismologists, define their scope of work, coordinate their work with the overall program, and ensure that owners are not victimized by unnecessary or impractical studies.

During a seismic safety conference about fifteen years ago, a geotechnical expert was expounding on the sophisticated techniques his firm had used to predict site-specific earthquake ground motion for his client. His study had been the most recent of a series of analyses by various consultants and agencies covering the site of a major facility that included many unsafe buildings that housed hazardous materials. At that point in time, these analyses had absorbed almost ten years during which time a damaging earthquake had not taken place. A well-known earthquake engineer asked, "Haven't we analyzed this site enough? Isn't it time to design corrective measures to upgrade the seismic resistance of the unsafe buildings at this site." The consultant's reply was, "Well, no, not really, because the state-of-the-art is changing all the time." Obviously, the specialist was more interested in analysis for its own sake than he was in mitigating the seismic safety hazards that existed there.

When submitting a proposal or being interviewed for potential selection to review existing buildings for seismic safety, most firms are compelled to choose highly specialized consultants to help them compete for the appointment. Normally, requests for proposals stimulate this response, thus setting the stage for the most sophisticated approach rather than the most effective and efficient. As a consequence, the leader for the appointed firm, usually the project manager, is likely to follow the profitable path of least resistance, letting the client-manager fall prey to more complex and time-consuming methodology, analysis, and reporting than is necessary to do the job. Unfortunately, this scenario is a wide spread and costly problem that is very detrimental to achieving timely seismic safety. Fortunately, it doesn't have to be this way. Reputable firms that are experienced in earthquake engineering know what is required and what is not required. With the proper direction and encouragement from clients, these firms can steer a more practical path that saves clients from wasteful expense and mitigates the hazards much more expeditiously. However, to achieve this end, the request for proposal and the criteria for selection must be written with this objective in mind.

Selecting the right structural engineering firm to counsel a practical way through the complexities and pitfalls that can befall earthquake safety programs is the most important decision managers can make.

This is also true when selecting geotechnical consultants. The level of sophistication in state-of-the-art techniques for predicting the intensity of ground shaking is intimidating. There is a strong tendency for both consultants and clients to believe the predictions to be more accurate than history shows they are. This tendency may lead participants to spend more money and time than the exercise is worth. The illusion of security thus developed is apt to be in direct proportion to the degree of sophistication applied.

The watchword is to keep the site investigation straightforward and simple, and rely more heavily on design than prediction.

Even when structural dynamics is to be employed, selection of an effective ground-motion input can be a relatively simple matter. There is little to be gained by exhaustive site studies because history shows that the prediction of ground motion is indeed an inaccurate science. The inaccuracies of input can generally be accommodated in good structural design. It is important to select geotechnical specialists who understand this.

Potential earthquake engineering and geotechnical consultants should be asked to explain in understandable terms how they expect to approach the project, what techniques will be applied, and what they expect to find. They should provide examples of previous work, names of clients, and cost histories. Clients should be sure that the lead consultants selected have strong design experience with comparable projects and have made field investigations of earthquake damage.

The Balanced Program

An effective earthquake safety program is analogous to an effective lateral-force-resisting system; it should have no weak links. Several basic precautions should be taken in establishing a program; of primary importance are the following six:

First, someone has to be responsible for code and regulation enforcement to ensure that facilities are designed and constructed to meet DOE orders, standards, and designated building-code provisions. Code provisions often require interpretation for specific applications. The best way to ensure that these provisions and regulations are properly interpreted and enforced is to formally appoint one individual as the *Building Official* for the site. This person should be knowledgeable about building and fire codes and a licensed engineer or architect. This appointment should be properly delegated from the manager or director of the site. *The Building Official should be given authority to review and approve all facilities design before construction can begin.* If this is not done, chances are that code enforcement will be diffused and ineffective. Worse yet, enforcement may be more susceptible to the pressures of the situation than to the intent of the code.

Second, make certain that planned new buildings are not being inadequately designed while the process of reviewing existing buildings for seismic safety is underway. This seems like a profound admonition, but the probability that it will happen is very real. It can be avoided by using a third-party plan-check or *peer review* prior to construction to ensure that designs for new structures and retrofit projects will adequately resist earthquakes. It is embarrassing for managers to find that a newly designed and constructed building is worse than an old one, but it happens.

Design criteria should be clearly defined and readily usable. Applicable standards and model codes should be used for buildings that do not require higher criteria by regulation. Complex approaches or criteria should not be applied unless the need is clearly established. Criteria should be practical. At most DOE sites, minor building modifications, experimental setups, equipment installations, cabinetry, nonstructural components, and miscellaneous other projects are usually designed by architects, mechanical engineers, designers, or other nonstructural engineers who have little background in seismic analysis and design. Nevertheless, if the criteria are understandable and straightforward, these minor subprojects will be designed and built with adequate earthquake resistance. The more significant structural problems should be handled by licensed structural engineers. Also, research or production facilities, particularly those using hazardous materials, should be carefully reviewed for seismic safety by structural engineers. Facilities using hazardous materials should be reviewed with the assistance of hazardous materials experts and the designated *Fire Marshal* (or *Fire Chief*) for the site. *A professional engineer's stamp and signature as well as a third-party review should be required whenever life safety is involved.*

Third, review the site for geologic and seismic hazards. Potential conditions that are inherently hazardous in ground shaking should be identified. These may include the following:

- Unstable slopes and existing landslides
- Areas of low-density granular soils subject to densification and subsidence
- Areas of low-density granular soils subject to liquefaction
- Areas where sensitive clays may be subject to strength loss under heavy ground shaking
- Areas where flooding would occur if an up-slope levee or dam failed.

Active faults should be identified and a geologic map of the site developed.

The site review need not be rigorous in detail unless potential hazards pose a high risk for a specific existing building or lifeline. If a new building or improvement is planned, the specific siting should be examined in more detail. *The main point is to recognize potential hazards and take them into account.* For example, it would be folly to permit the typical one-third increase in allowable soil bearing capacity for seismic loading in an area of sensitive clays subject to strength loss under ground shaking.

The initial review should be quite broad and general in character. It is important that it be carried out by geologists or geotechnical engineers who understand the nature of soil dynamics, preferably people who have experience with earthquakes. Generally, except for fault rupture, each of the potential hazards that may exist can be mitigated through standard stabilization practices or by simply avoiding them in the case of new construction. Sometimes fault movement can be accommodated, or the effect of fault movement mitigated, if it is known where surface ruptures are likely to occur.

Fourth, survey and evaluate all existing buildings and structures to determine their earthquake safety ratings. Structural engineers experienced in earthquake damage investigation should do the job. The assessment should be kept simple. Experienced earthquake engineers know which types of buildings are hazardous. A basic requirement is to find out what has to be done to ensure that each building has a predictable lateral-force-resisting system. Establish a plan to carry out needed retrofit projects on a priority basis, but don't delay mitigation of high hazard conditions in order to see the whole picture. Start one step at a time, reducing liability on a priority basis.

Given a limited budget, it is important to determine which building projects will provide the greatest benefits for the money spent for improvements in life safety and property damage. For life safety, the procedures found in

Evaluating the Seismic Hazard of State Owned Buildings, California Seismic Safety Commission, SSC79-01, by McClure, Degenkolb, Steinbrugge, and Olson, are recommended. For property damage, refer to Fig. 10 and its supporting text in the report entitled *Estimation of Earthquake Losses to Buildings (Except Single Family Dwellings)* by Algermissen, Steinbrugge, and Lagorio, U.S. Geological Survey (USGS), Open-File Report 78-441. These references provide a practical rationale for a general approach to cost-effectiveness. Of course, practical risk management must also address socio-political issues that encompass and plague earthquake safety programs and pose questions of public and personal liability. These aspects of risk management are discussed in the Foreword to Chapter 12.

Fifth, make an earthquake-hazards survey of the contents of each building including operational equipment, hazardous materials storage, and nonstructural building elements and systems. Obvious hazards, such as loose-item overhead storage, should be immediately corrected by building managers or operations supervisors. Most operational hazards are obvious by simply observing the scene and imagining an earthquake taking place. Tipping hazards, such as storage cabinets, tall files, library shelving, and similar furnishings, should be braced or anchored. Tie-downs or restraints should be installed on plant equipment such as transformers, emergency generators, tanks, elevator drives, fans, motors, and similar units. Apply a simple and judgmental priority system to use limited resources economically.

Sixth, develop an emergency plan to recover from a destructive earthquake. Apply the scenario technique to develop a probable model for the aftermath of an intense earthquake. Use department heads who will have to handle the recovery to lead the planning effort. Reduce obstacles to recovery by eliminating obvious hazards and ensuring that the supplies and equipment that will be needed in an emergency will *in fact* be available. Lifelines, such as water supply lines, power systems, storm and sanitary sewers, transportation, and communications systems also should be surveyed with earthquakes (and seismically induced fires and landslides) in mind. *Be sure to take into account the potential for loss of service from offsite utilities suppliers.* The consequences of utilities losses can be mitigated by careful emergency planning, and the potential for loss of a given facility reduced by *hardening* the lifelines that would likely be in jeopardy during an earthquake.

Self-help planning, preparation, and training should be key elements in any emergency-response plan for earthquake safety. Make sure that building managers and operations supervisors understand this fact and let them take the lead in the preparation of local emergency plans.

In the chapters that follow, each facet of a balanced earthquake safety program is discussed by engineers who have a great deal of experience with earthquakes. Each has considerable knowledge about subjects covered in other chapters so there is some overlap. However, it is intended that each chapter can be read independently of the others.

As one might expect, sometimes a healthy difference of opinion is expressed. These differences reflect the perspectives of different experts but tend to give managers valuable insight into the practical state-of-the-art. They also remind us that often there is more than one answer to a given problem. When a problem is particularly *sticky* and costs, risks, or liabilities are high, it is unquestionably worthwhile to get more than one opinion.

The question arises, how do managers resolve technical differences of opinion between two consultants on subject-matter about which managers feel inadequate.

The best answer lies in managers' usual role: managing the multidisciplinary functions of a technical complex such as a major research and development laboratory or a sophisticated production facility. The development of good communication and mutual trust with practical earthquake engineering consultants will provide managers with an extension of expertise in this specialized field much as it does in any other specialized field under their management. In the end, the responsibility must lie with managers, and it is important to realize ahead of time that technical differences of opinion are apt to arise about earthquake safety management. Responsible earthquake engineering consultants will be more interested in the primary goal of practical earthquake safety rather than earthquake engineering for its own sake. This extension of expertise through selection of wise counsel is a challenge that most managers face in other facets of their responsibilities.

When questions regarding technical differences of opinion or criteria persist, it is important that they are resolved by some due process within a technical framework that will stand the test of future technical and legal review. Designers and managers should be reasonably protected by the due process involved, assuming that they each fulfill their professional responsibilities satisfactorily. This subject involves considerations in risk management that are discussed more thoroughly in Chapter 12.